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METHOD FOR MEASURING TEMPERATURE USING A REMOTE, PASSIVE, CALIBRATED RF/RFID TAG INCLUDING A METHOD FOR CALIBRATION

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A system for tracking environmental parameters, such as temperature, associated with a package during transportation and storage thereof, comprises a passive RFID (Radio Frequency Identification) tag adapted for containment within the package and at least an RFID reader adapted to communicate with such passive RFID tag. The tag includes means for sensing an environmental parameter, such as temperature, means for storing information respecting such parameter, and means for transmitting such information upon activation by such reader. The reader includes means for activating such tag, means for receiving and storing information received from such tag, and means for making such received information available to an interested party. The system may also include a master tag for external association with the package, the master tag prompting the slave tag to transmit data at specific intervals. If the sensed parameter is temperature the slave tag may utilize a tick oscillator, the transmission frequency of which changes in response to temperature changes, the master tag then determining the temperature on the basis of the frequency change. Data supplied from the esp@cenet database - Worldwide bdf

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(54) METHODE DE MESURE DE LA TEMPERATURE A L'AIDE D'UNE ETIQUETTE RF/RFID ETALONNEE, PASSIVE, ELOIGNEE, Y COMPRIS UNE METHODE D'ETALONNAGE

(54) METHOD FOR MEASURING TEMPERATURE USING A REMOTE, PASSIVE, CALIBRATED RF/RFID TAG INCLUDING A METHOD FOR CALIBRATION

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METHOD FOR MEASURING TEMPERATURE USING A REMOTE, PASSIVE, CALIBRATED RF/RFID TAG INCLUDING A METHOD FOR CALIBRATION

The present invention relates to a system that includes a passive, remote radio frequency identification (RFID) tag, and a control device, such as an active smart RFID tag or RFID reader/writer that can communicate with the passive tag giving it instructions and receiving data from it and that can analyze and store data so received. In the case of this control device being an active smart RFID tag, the system would further require a reader/writer that can instruct the active RFID tag and can read data created during use of the tags. The system will be utilized primarily in the transport and storage field, or any other field of use where detecting changes in temperature at distance without the use of a direct probe is desirable. The system utilizes a unique means for determining temperature, which means forms part of this patent application. This invention further claims a methodology of calibration to provide accurate temperature measurements (in the range of +/- 0.1 degree C).

BACKGROUND OF THE INVENTION

Devices to measure temperature in transported or stored goods are widely known. Inexpensive temperature sensing devices are generally designed to record only a single excursion outside a preset temperature window. More expensive temperature logging devices are typically bulkier and too costly for single use or disposable applications. A further limitation of prior art is the requirement to retrieve a tag from a shipping box to take a reading or download data from it.

There are many instances where it is desirable to determine and record the temperature at many points during the transportation or storage of a product or load. Electronic sensing and recording devices that can do this are available; they include thermistors or other temperature sensors, a clock, a battery, a memory in which temperature data are recorded, and some form of output mechanism (such as a plug-in port) whereby the recorded data can be read for interpretation by an interested party at a later time. These devices are large in size compared to the disposable tags, and significantly more expensive. They are generally reusable. In some cases, for example where the container's size is small relative to the size of the sensing and recording device or extreme temperatures that would affect battery performance are of interest, they require probes containing a temperature sensor that destroys the integrity of the container. Where the container is large enough to accommodate a sensing and recording device, the device must be removed from the container when it reaches its destination to allow it to be reused.

Passive RFID tags are in wide use for identifying and tracking all manner of packages and items. RFID technology uses electromagnetic or electrostatic coupling in the radio frequency (RF) range of the electromagnetic spectrum to identify uniquely an object of interest. RFID is increasingly supplementing or replacing bar coding for identification purposes and providing electronic packing slip functions in the shipping and logistics industry as it does not require direct contact or line-of-sight scanning.

A passive RFID system comprises an antenna and transceiver (usually combined as a reader) and a transponder (RFID tag). The antenna generates a RF signal that activates the RFID tag. The activated tag then transmits data back to the antenna. The data may be used to notify a logic controller to initiate an action, or stored for subsequent retrieved by an interested party.

In response to the size and cost issues, Petersen and Wilson (Environment Monitoring and Recording Tag and Reading System – U.S. Patent Pending 2002) have described an active or smart RFID Tag system for monitoring and recording environmental conditions including temperature, that is small in size, relatively inexpensive, and can transmit its data to a reader via wireless means. However it is sufficiently expensive in its manufacture that it could be uneconomical as a single use or disposable device for most applications, necessitating its removal from the container or package at its destination, for the purpose of later re-use. A further limitation is the adverse effect of decreasing temperature on the battery, making the device impractical for very cold applications (such as monitoring dry-ice packaged goods) without the addition of a temperature probe containing a thermistor, which destroys the integrity of the package, or the use of expensive low temperature battery technology.

SUMMARY OF THE INVENTION

The invention combines a low cost passive RFID tag (slave tag) with an active RFID master tag and a RF writer/reader in a system that senses and records temperature a preprogrammed intervals. The low cost of the slave tag makes it feasible to be used as a disposable temperature sensor.

A further implementation of this invention combines a low cost passive RFID tag (slave tag) with an RF writer/reader in a recording system, omitting the master tag.

The slave tag is inserted in a package or container whose internal temperature is of interest. The master tag polls the slave tag at pre-programmed intervals via RF signal, and the slave tag transmits data (such as its unique ID and/or manufacturer code) back to the master tag by RF signal. The master tag can then determine the temperature of the

environment into which the slave tag has been inserted by way of calculating the frequency shift caused by such ambient temperature from its nominal calibrated frequency (see below for method of calibration).

The master RFID tag comprises an integrated circuit with programmable or re-programmable procedure memory, battery, antenna, clock, high-stability oscillator such as piezo-electric, quartz or ceramic resonator, and volatile or non-volatile data memory. The master tag can be pre-programmed at the time of manufacture or can be programmed prior to use using the RF writer/reader. At programmed intervals, the temperature data calculated from the frequency shift during data transmission sessions by the slave tag are stored in the master tag's data memory. The stored temperature data can be downloaded via RF writer/reader by someone interested in the temperature to which the container contents have been exposed.

The slave tag comprises a procedure memory programmed with calibration data (if required, as described below) optional data such as ID, manufacturer codes, electronic packing slip information etc., Manchester-type phase encoder, oscillator whose frequency is temperature sensitive such as a tick oscillator, and a resonator such as an antenna coil, printed antenna, ceramic antenna, etc.

In a further aspect of the system, the temperature sensitive oscillator of the slave tag replaces a thermistor or other direct temperature sensing device as the means of determining the temperature, eliminating the need for a battery in the slave tag. This reduces the cost of manufacturing the slave tag and eliminates the problem of a battery's voltage being temperature sensitive. In principle, any ISO standard RFID tag can be used for this function, adding little or no additional cost to logistic systems already utilizing such RFID tags to track shipments.

In this system, temperature is measured by comparing the stable oscillator frequency of the master tag to the frequency of the slave tag's tick oscillator, a semi-conductor device whose frequency is predictably dependent on temperature. The master tag's antenna is calibrated to receive signals in the frequency range of interest, determined by the range of temperature to which the slave tag might be exposed and the range of frequencies that would result from such temperatures. The temperature at the slave tag would influence the tick count of its oscillator, which would be known to have a predictable change in tick frequency in response to changes in temperature.

$$\boldsymbol{Penc = Tf\,(temp)}$$

Where ***Penc*** = period of Manchester encoder pulses; ***Tf*** = sigmoid type function; **temp** = temperature

The relationship between temperature and frequency would be calibrated prior to use and stored in the procedure memory of the master tag. Deviation of the returning RF signal's frequency from that of the stable oscillator in the master tag would be determined and compared to the frequency-temperature calibration data for the slave tag's oscillator. The resulting calculated temperature at the slave tag would then be recorded in the master tag's temperature data memory. At a later time, a party interested in the temperature to which the container was exposed could download the stored temperature data from the master tag using a RF or other type of reader.

In use, the slave tag is placed inside a container at the time of shipping or at the time of manufacture of such container. The master tag is placed outside the container in close proximity, such as attached to the container by adhesive or other means. The master tag is programmed to cause the slave tag to transmit data to it at intervals of interest to the user.

The master tag polls the slave tag by transmitting an RF signal that excites the slave tag's tick oscillator and provides energy to the device. The slave tag responds by transmitting an RF signal that can be detected by the master tag. Because of the sensitivity of the slave tag's tick oscillator to changes in temperature, its signal will deviate from the master tag's RF frequency according to a predictable relationship.

Calibration data for the slave tag's temperature-frequency relationship will be stored either in the slave tag's or master tag's memory, and the difference in frequency from the transmitted RF signal to the received RF signal will be applied to the calibration data to determine the temperature at the slave tag. This will be time stamped and recorded in the master tag's data memory.

To calibrate the slave tag's temperature-frequency relationship

$$\boldsymbol{Penc} = \boldsymbol{Tf}\,\textbf{(temp)}$$

Penc is determined under two or more specific temperatures $\mathbf{temp_1}$..... $\mathbf{temp_n}$. To achieve this, the slave tag could be inserted into a temperature insulated chamber containing a thermoelectric element (*effet Peltier*). The temperature could be changed rapidly and with precision, allowing $\boldsymbol{Penc_1}$..... $\boldsymbol{Penc_n}$ to be determined. The specific function can then be calculated for this tag sample and stored in the procedure memory of the slave tag from which it would be downloaded to the master tag or writer/reader to be used in temperature determination. This would obviate the necessity of uniquely pairing slave and master tags. The temperature-frequency function might equally be stored in the procedure memory of the master tag if specific master-slave pairs are to be used. From this function the temperature can be computed for any value of ***Penc***.

To provide very exact temperature measurements (+/- 0.1 degree C), each tag would be calibrated. However, in large scale implementation

calibration could be generalized to the design and components of a particular type of slave tag (such as a standard RFID tag produced by a particular manufacturer) and therefore avoid the requirement for individual calibration of each tag. In such cases, a generic calibration coefficient would be sufficient to provide temperature measurements in the +/- 1 degree C range, if not better.

As described by Petersen and Wilson (2002), the temperature data can be retrieved from the master tag by an interested party. The master tag can be single use or multiple use and may be reprogrammable. Petersen and Wilson (2002) describe various means by which this might be done. The slave tag can also be single use or reusable

In a variation of the invention, the master tag is omitted from the system and the passive RFID slave tag is inserted into a package or container. Each time the package passes through a RF reader at a loading station, unloading station, sorting station, warehouse or delivery point, as is currently in widespread use for tracking the movement of such packages, the temperature at the RFID tag at that time could also be determined and processed (stored, downloaded) by the reader. This would allow a central database to keep track of the time and internal temperature of the package at each waypoint in systems where such packages are already being scanned and tracked using barcodes and/or RFID tags.

In a further variation of the invention, the package ID, electronic packing slip, other logistics related information, manufacturer code (to facilitate "generic" calibration – see above) and temperature sensitive components could be combined in a single passive RFID tag, thereby eliminating the requirement for additional hardware to provide the benefit of temperature measurements, by utilizing RFID readers and passive RFID tags already incorporated into the logistics infrastructure of shipping and courier companies.